Claims

[c1] A magnetically enhanced sputtering source comprising:

a) an anode;

b) a cathode assembly that is positioned adjacent to the anode and forming a gap therebetween, the cathode assembly including a sputtering target;

c) an ionization source that generates a weakly-ionized plasma proximate to the anode and the cathode assembly;

d) a magnet that is positioned to generate a magnetic field proximate to the weakly-ionized plasma, the magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target; and

e) a power supply that produces an electric field across the gap, the electric field generating excited atoms in the weakly ionized plasma and generating secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms, thereby creating a strongly-ionized plasma having ions that impact a surface of the sputtering target to generate sputtering flux.

[c2] The sputtering source of claim 1 wherein the power supply generates a constant power.

[c3] The sputtering source of claim 1 wherein the power supply generates a constant voltage.

[c4] The sputtering source of claim 1 wherein the electric field comprises a quasi-static electric field.

[c5] The sputtering source of claim 1 wherein the electric field comprises a pulsed electric field.

[c6] The sputtering source of claim 1 wherein a rise time of the electric field is chosen to increase the ionization rate of the excited atoms in the weakly-ionized plasma.

[c7] The sputtering source of claim 1 wherein the weakly-ionized gas reduces the probability of developing an electrical breakdown condition between the anode and the cathode assembly.

[c8] The sputtering source of claim 1 wherein the ions in the strongly-ionized plasma impact the surface of the sputtering target in a manner that causes substantially uniform erosion of the sputtering target.

[c9] The sputtering source of claim 1 wherein the strongly-ionized plasma is substantially uniform proximate to the sputtering target.

[c10] The sputtering source of claim 1 further comprising a substrate support that is positioned in a path of the sputtering flux.

[c11] The sputtering source of claim 10 further comprising a temperature controller that controls the temperature of the substrate support.

[c12] The sputtering source of claim 10 further comprising a bias voltage power supply that applies a bias voltage to a substrate that is positioned on the substrate support.

[c13] The sputtering source of claim 1 wherein a volume between the anode and the cathode assembly is chosen to increase the ionization rate of the excited atoms in the weakly-ionized plasma.

[c14] The sputtering source of claim 1 wherein the ionization source comprises an electrode.

[c15] The sputtering source of claim 1 wherein the ionization source comprises a DC power supply that generates an electric field proximate to the anode and the cathode assembly.

[c16] The sputtering source of claim 1 wherein the ionization source comprises an AC power supply that generates an electric field proximate to the anode and the cathode assembly.

[c17] The sputtering source of claim 1 wherein the ionization source is chosen from the group comprising a UV source, an X-ray source, an electron beam source, and an ion beam source.

[c18] The sputtering source of claim 1 wherein the magnet comprises an electro-magnet.

[c19] The sputtering source of claim 1 wherein the sputtering target is formed of a material chosen from the group comprising a metallic material, a polymer material, a superconductive material, a magnetic material, a non-magnetic material, a conductive material, a non-conductive material, a composite material, a reactive material, and a refractory material.

[c20] A method of generating sputtering flux, the method comprising:
a) ionizing a feed gas to generate a weakly-ionized plasma proximate to a sputtering target;
b) generating a magnetic field proximate to the weakly-ionized plasma, the magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target; and
c) applying an electric field to the weakly ionized plasma that excites atoms and that generates secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms, thereby creating a strongly-ionized plasma having ions that impact a surface of the sputtering target to generate sputtering flux.

[c21] The method of claim 20 wherein the applying the electric field comprises a applying a quasi-static electric field.

[c22] The method of claim 20 wherein the applying the electric field comprises applying a substantially uniform electric field.

[c23] The method of claim 20 wherein the applying the electric field comprises applying an electrical pulse across the weakly-ionized plasma.

[c24] The method of claim 23 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse that increases an ionization rate of the strongly-ionized plasma.

[c25] The method of claim 23 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse that reduces a probability of developing an electrical breakdown condition proximate to the sputtering target.

[c26] The method of claim 23 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse that causes the strongly-ionized plasma to be substantially uniform in an area adjacent to a surface of the sputtering target.

[c27] The method of claim 23 wherein the electrical pulse comprises a pulse having a current density that is greater than $1 A/cm^2$.

[c28] The method of claim 23 wherein the electrical pulse comprises a pulse having a pulse width that is greater than 1.0 microseconds.

[c29] The method of claim 23 wherein the electrical pulse comprises a pulse train having a repetition rate that is substantially between 0.1Hz and 1kHz.

[c30] The method of claim 20 wherein the ions in the strongly-ionized plasma impact the surface of the sputtering target in a substantially uniform manner.

[c31] The method of claim 20 wherein the strongly-ionized plasma is substantially uniform proximate to the sputtering target.

[c32] The method of claim 20 wherein the peak plasma density of the weakly-ionized plasma is less than about $10^{12} cm^{-3}$.

[c33] The method of claim 20 wherein the peak plasma density of the strongly-ionized plasma is greater than about $10^{12} cm^{-3}$.

[c34] The method of claim 20 further comprising forming a film from the sputtering flux on a surface of a substrate.

[c35] The method of claim 34 further comprising controlling a temperature of the film.

[c36] The method of claim 34 further comprising applying a bias voltage to the film.

[c37] The method of claim 20 wherein the ionizing the feed gas comprises exposing the feed gas to an electric field.

[c38] The method of claim 20 wherein the ionizing the feed gas comprises exposing the feed gas to an electrode that is adapted to emit electrons.

[c39] The method of claim 20 wherein the ionizing the feed gas comprises exposing the feed gas to at least one of a UV source, an X-ray source, an electron beam source, and an ion beam source.

[c40] A magnetically enhanced sputtering source comprising:

a) means for ionizing a feed gas to generate a weakly-ionized plasma proximate to a sputtering target;

b) means for generating a magnetic field proximate to the weakly-ionized plasma, the magnetic field substantially trapping electrons in the weakly-ionized plasma proximate to the sputtering target; and

c) means for applying an electric field that excites atoms in the weakly ionized plasma and that generates secondary electrons from the sputtering target, the secondary electrons ionizing the excited atoms, thereby creating a strongly-ionized plasma having ions that impact a surface of the sputtering target to generate sputtering flux.